August Dvorak (1894–1975): Early Expressions of Applied Behavior Analysis and Precision Teaching

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August Dvorak is best known for his development of the Dvorak keyboard. However, Dvorak also adapted and applied many behavioral and scientific management techniques to the field of education. Taken collectively, these techniques are representative of many of the procedures currently used in applied behavior analysis, in general, and especially in precision teaching. The failure to consider Dvorak's instructional methods may explain some of the discrepant findings in studies which compare the efficiency of the Dvorak to the standard keyboard. This article presents a brief background on the development of the standard (QWERTY) and Dvorak keyboards, describes parallels between Dvorak's teaching procedures and those used in precision teaching, reviews some of the comparative research on the Dvorak keyboard, and suggests some implications for further research in applying the principles of behavior analysis.

Key words: Dvorak, precision teaching, scientific management, keyboard skills, verbal behavior

Early behaviorism and scientific management, which were both part of the larger scientific and social developments occurring in the early part of the century, shared many similarities. The scientific management movement included people such as Henry L. Gantt, Frank B. Gilbreth, and Frederick W. Taylor. These scientific managers spent much time conducting time-motion, piece-work, and stop watch studies. From their research in "human engineering," these individuals discovered numerous methods for increasing human performance. Some of these methods were also used by early behaviorists and included schedules of reinforcement, identification of simple and repeatable behavioral units, and the use of charts for showing data (Gantt, 1919/1974; Schwartz & Lacey, 1982; Taylor, 1911/1947).

Influenced by both the behavioral and scientific management movements, August Dvorak, a professor of education at the University of Washington, was resourceful in applying many of the behavioral principles and scientific management techniques to the field of education. Dvorak, Merrick, Dealey, and Ford (1936), for example, frequently refer to the research of behaviorists such as E. R. Guthrie, C. L. Hull, and E. L. Thorndike and acknowledge their strong technological debt to Frank Gilbreth, a leader of the scientific management movement. Dvorak was particularly interested in increasing typing efficiency among student typists. Taken collectively, his teaching strategies were a forerunner of some of today's precision teaching techniques (e.g., McGreevy, 1984; Pennypacker, Koenig, & Lindsley, 1972; White, 1986). Dvorak also focused his attention on the development of a new typewriter keyboard which he believed would revolutionize typing by increasing its efficiency.

Dvorak's name is usually associated with his keyboard rather than his instruction, and the close connection between the two has not been fully appreciated. To clarify the significance of Dvorak's work, a brief history of the typewriter, which includes the development of two types of keyboards, is presented below. This is followed by a discussion of the conflicting research findings regarding the efficiencies of these keyboards and possible reasons for the discrepant findings, which include Dvorak's methods of instruction. Some implications are then suggested that include how the keyboard remains an exceptionally appropriate instrument for behavioral research, particularly in the area of verbal behavior.

History of the Keyboard

The present arrangement of most typewriter keyboards is largely credited to

Christopher Latham Sholes. Sholes, Carlos Glidden, and Samuel Soule filed their first patent for a typewriter in 1867. This keyboard consisted of an alphabetical arrangement of keys which, unfortunately, posed a major problem. Adjacent typebars tended to jam when the keys for these typebars were struck in rapid succession by "hunt and peck" typists. In efforts to alleviate this problem, Sholes experimented with different key arrangements for six years until he finally developed the QWERTY keyboard (named for the sequence of characters in the top row of letters). This keyboard was advantageous because the typebars most frequently used in succession were separated from each other in the type-basket (Adler, 1973). Despite the changes in keyboard arrangement, some vestiges of the alphabetical keyboard remained (e.g., the *fghjkl,* and the *op* letter sequences). In 1873, E. Remington and Sons (the famous arms maker) secured the manufacturing rights to Sholes' 'Type Writer.' Further modifications included placing the letter "R" on the upper row, which enabled salespeople to impress prospective customers by rapidly typing the brand name, TYPE WRITER, using only the top row of keys (David, 1985).

Despite keyboard modifications, the future of the typewriter was tenuous in the 1870s. The nation was in the midst of an economic depression and Remington was on the verge of bankruptcy. Most companies, let alone individuals, could not afford the $125 for a piece of office equipment (David, 1985). However, by the 1880s the economic crisis was over and the demand for typewriters began soaring. Faced with increased demand, numerous companies found typewriter manufacturing a lucrative business. Some of the many typewriters made during this time included the Crandall, American, Hall, Columbia, and Morris (Lemmons, 1982). Interestingly, each of these typewriters had a different keyboard arrangement.

In the late 1880s, the introduction of "touch" typing played a vital role in the establishment of the QWERTY as the standard typewriter keyboard from which most future keyboards were designed. In a well-publicized typing contest in Cincinnati in 1888, Frank E. McGurrin, who used "ten-fingered" touch typing on a Remington three-row QWERTY typewriter, decisively defeated Louis Taub, who used "four-fingered" hunt and peck typing on a rival non-QWERTY keyboard with six rows for upper and lower case. Although Remington could interpret this victory as a boost for its keyboard, the superiority of touch typing was the significant factor. For some time after the commercial introduction of the typewriter in 1874, the typical typist used one finger on each hand to type while looking at the keyboard and searching for the keys. This was later nicknamed the Columbus system because a discovery was made each time a key was struck (Yamada, 1980). In this hunt and peck typing, which is analogous to Michael's (1985) *selection-based* verbal behavior, visual scanning is essential and the topography of the arm, hand, and finger movements that select a particular key may vary considerably on each return to that key without being precisely distinguished from the movements to other keys. In contrast, in touch-typing, which is analogous to Michael's *topography-based* verbal behavior, visual scanning is replaced by arm, hand, and finger movements that are unique and more precise for each separate key. The improved efficiency in typing when kinesthetic, proprioceptive cues replace visual cues is similar to the improved efficiency in communication when topography-based speech replaces selection-based pointing.

Since touch typing required motor responses that were conditioned to a particular arrangement of keys, a universal keyboard was needed so typists could use their typing skills across all typewriter models. The QWERTY keyboard of the Remington typewriter became the standard primarily because more Remington typewriters were on the market (Litterick, 1981). As more and more companies purchased typewriters with QWERTY keyboards, more and more typists learned QWERTY touch typing. "Retraining" costs on different typewriters were min-

imized when QWERTY typists continued to type on QWERTY keyboards. Even when the more "scientific" keyboard of the Ideal typewriter was developed for touch typing, it failed to replace the standard keyboard because too many typists had already learned touch typing via the QWERTY.

Perhaps the most serious challenge to the QWERTY typewriter occurred in 1932 with the patenting of the Dvorak keyboard, which was specifically designed for touch typing. Influenced by Gilbreth's time and motion studies of expert typists, Dvorak believed that the principles of simple motion, rhythmic sequence, and short movement could be applied to the keyboard and thereby increase key pressing efficiency (Hoffer, 1985). Specifically, Dvorak (1943) believed that efficiency could be increased by correcting six handicaps inherent in the QWERTY. Incorporating features of the Ideal keyboard, Dvorak developed a new keyboard configuration to correct these six handicaps. Corrections for these handicaps included: 1) Decreasing the left hand overload from 57% to 44% so more characters were struck by the stronger, right hand; 2) decreasing specific finger overloads so all fingers were assigned work proportionate to their skill and strength; 3) increasing the amount of home row typing from 32% to 70%; 4) reducing finger motions among rows by 90%; 5) increasing the number of words which were typed exclusively on the home row from approximately 100 to over 3,000; and 6) reducing the number of words (from over 3,300 to 61) which were typed only by the weaker, left hand.

Dvorak proceeded to train students on his new keyboard using behavioral and scientific management principles of instruction. His student typists made excellent progress, and before long Dvorak began entering his Dvorak-trained typists in contests held by the International Commercial Schools Contest (ICSC) in Chicago, Illinois. For many years, the Dvorak typists placed first in each of the class events, surpassing other contestants who had more training. However, by 1937, members of the ICSC Committee

were disgruntled with the "unfair competition" and barred all Dvorak typists from the contest (Parkinson, 1972). Although Dvorak and his typists were later readmitted to the ICSC, the controversy continued. Some of the typists using the QWERTY typewriters objected to being placed next to Dvorak typists because the noise from the high key pressing frequencies of the Dvorak keyboard was disturbing. The situation worsened and in subsequent years typewriters with Dvorak keyboards at the ICSC were sabotaged, requiring Dvorak to hire security personnel to guard his typewriters.

Early studies comparing typing frequencies generally favored the Dvorak over the QWERTY by a wide margin. During the 1930s, an experimental typing program was initiated by the Tacoma School District in Washington. Approximately 2,700 students served as subjects in this project. Results of the program indicated that senior high students learned to use the Dvorak in 1/3 the time it took to learn the QWERTY. Moreover, junior high students attained frequencies in one semester that normally required one full year of instruction using the standard keyboard (Parkinson, 1972). In the late 1930s, Dvorak trained seventh and eighth grade students using the Dvorak keyboard at the University of Chicago demonstration school. Although class instruction was less than 50% of the time allocated for students learning the QWERTY, performance of the Dvorak-trained students exceeded that of the other students (Neill, 1980). In 1944, the U.S. Navy Department conducted a study comparing typing frequencies of typists using the Dvorak and QWERTY keyboards. Results of the study indicated that Dvorak typists achieved three times the frequencies in net typing speed (24.2 vs. 8.1 n.w.p.m.) when compared to QWERTY typists, and did so in approximately half the training time (83 hours vs. 157.6 hours). The combination of increased frequencies in typing speed with shorter training is hereafter referred to as typing "gains."

In spite of this accumulating evidence in its favor, there was little adoption of

the Dvorak keyboard. Although it is frequently difficult to replace a well-established standard, it was even more difficult to introduce a new standard during the economic depression of that time. Dvorak's claims for increasing typing productivity through using the Dvorak keyboard were ill-received, possibly because typewriter manufacturers interpreted his claims as meaning employers would hire fewer typists and purchase fewer typewriters. Consequently, typewriter manufacturers were reluctant to promote a keyboard that could hinder typewriter sales even after the economy improved (Cassingham, 1986). Other factors hindering the adoption of the QWERTY keyboard have also been suggested (Yamada, 1980).

Dvorak's Precision Teaching Techniques

Throughout the late 1950s and 1960s, there was a paucity of research regarding keyboard efficiencies. However, with the increase in computer usage during the past decade, there has been renewed interest and research in keyboard layouts. Interestingly, this latest wave of research is somewhat mixed in its findings as to the advantages of the Dvorak keyboard. A large portion of this research does not support the earlier gains in typing speed for the Dvorak keyboard, which were reported for the final differences in performance on the Dvorak and QWERTY keyboards. For example, Gentner and Norman (1984) estimate 5 to 10% gains; Norman and Fisher (1982) estimate 5%; Kinkead (1975) estimates 2.6%; and Strong (1956) found greater gains in speed for the QWERTY keyboard. A smaller portion of this research (e.g., Hiraga, Ono, & Yamada, 1980; Yamada, 1980, 1983) gives more support to the results found by the earlier studies. For example, based on his review of selected studies, Yamada (1980) claims Dvorak users type 15 to 20% faster than QWERTY users for timed copy-typing of limited durations and 25 to 50% faster in routine production typing of everyday work.

Methodological problems may account for some of the disparity in the findings of these two groups. Some of the lower-gain studies, for example, were based on computer models containing assumptions that have been questioned (cf. Card, Moran, & Newell, 1983; Yamada, 1980). However, other factors may be involved. One such factor may be the different training techniques used in teaching Dvorak typists.

Dvorak not only used the principles of scientific management in designing the Dvorak Simplified Keyboard (DSK), but he also used them in training typists. These training techniques reflect strategies that are consistent with many present day tactics in applied behavior analysis as well as specific precision teaching practices. Conversely, many of the later studies comparing the Dvorak and QWERTY keyboards did not include Dvorak's teaching techniques. This difference may account for much of the discrepancy in results.

Some of Dvorak's teaching methods are listed below (Dvorak et al., 1936). Most of these (e.g., positive reinforcement and modeling) are considered good behavioral practices and therefore used throughout applied behavior analysis. Some (e.g., timed probes) are more characteristic of precision teaching's focus on frequency data and frequent measurement practices.

1. Reinforcement of correct responses. Influenced by an earlier study (Gilchrest, 1916), Dvorak understood the importance of reinforcement for modifying behavior. He recognized the value of social incentives and utilized tangible reinforcers for increasing typing accuracy. For example, "Praise . . . is a powerful typing incentive . . . there is usually something at which each student can excel. . . . More than any other incentive, your typing instructor may rely on recognition of special achievements. This incentive is systematized not only by the regular posting of superior scores under a student's name, but by buttons, printed ribbons, certificates, and other recognized emblems" (Dvorak et al., 1936, pp. 47–48).

2. Timed probes. Interested in the administration of daily, timed tests to his student typists, Dvorak stated, "Avoid

any excessive use of rhythm drills as such. The only efficient drills are short and lively and widely separated" (Dvorak et al., 1936, p. 310). The students were then encouraged to calculate the frequency for each administered probe. Stop watches were used to insure accurate measurements of time.

3. Warmup. Prior to each probe administration, Dvorak provided typists the opportunity for a brief "warming up" period in which reinforcers were not contingent on performance. Dvorak apparently recognized the relationship between warming up and increases in frequency. "A 'warming up' may be needed to offset the slow start" (Dvorak et al., 1936, p. 67).

4. Accuracy vs. frequency. Dvorak was concerned with both accuracy and frequency. However, believing that accuracy could be shaped once students attained high rates of typing, Dvorak placed a higher premium on frequency. "Not accuracy but its exaggeration is here condemned, and for two reasons. In the first place, accuracy is overstressed at the expense of fast motion. In the second place, overstressed accuracy distorts your typing by a distorted view of essentials" (Dvorak et al., 1936, p. 286). Dvorak further noted, "Within limits, however, the loss in accuracy with increased speed is relatively slight. It is only when speed becomes excessively fast that errors accumulate by leaps" (Dvorak et al., 1936, p. 292).

5. Modeling. In efforts to increase typing frequency, Dvorak used numerous strategies, one of which was modeling. Students with high rates of typing behavior served as models for beginning typists. Many of these demonstrations were filmed so student typists could later study the films; ". . . you can learn in practical ways by watching each skillful motion as the instructor or a slow-motion film demonstrates . . ." (Dvorak et al., 1936, p. 206).

6. Group contingency plans. Influenced by Sim's (1928) study for increasing performance, Dvorak utilized contests among typing classes within geographical regions. "The favored swing,

accordingly, is toward contests between whole class groups" (Dvorak et al., 1936, p. 51). Class typing scores were compared among schools and rewards were given to the class which had the highest performances.

7. Contracts. Dvorak frequently used contracts specifying frequency goals (e.g., 50, 60, or 100 words per minute) which students were to attain on various timed probes. Rewards were given for goal attainment.

8. Charts. Although Dvorak did not use the still undeveloped Standard Behavior Chart, he did use arithmetic progress charts for charting daily student progress. Realizing that charts functioned as an important tool for providing feedback, Dvorak stated, "Apparently each student does more when he competes with his own record and can see the results of his work" (Dvorak et al., 1936, p. 68).

9. Individual vs. group data collection. Dvorak stressed the need for students to chart individual typing progress rather than using class charts; "When all class scores are pooled, however, the effect is to throw a common blanket over the astonishing differences between you and other students . . ." (Dvorak et al., 1936, p. 446).

10. Celeration. Dvorak charted celeration lines using the freehand method; "Lay your ruler through the midst of these fluctuations [in frequencies] . . . to bring out a hidden line which gradually slants upward [celerates] for a complete speed gain of 26 words" (Dvorak et al., 1936, p. 438).

11. Acceleration. Dvorak was especially concerned when typing frequencies stabilized and no longer accelerated. He referred to the steady states as "plateaus" and recommended that plateaus be arrested by changing the teaching strategy or adjusting the reinforcers.

12. Self-recording. Dvorak encouraged his students to identify their errors, calculate their frequencies, chart their own data, and examine the relationship between their errors and speed. "(1) Upon your progress chart . . . you plot your gross words per minute for each test . . . (2) Upon the chart you plot also your net

words per minute for each test ... (3) Upon this chart you then plot your errors after each test ... At once you can visualize concretely in balanced fashion the changing speed and accuracy of your typing outputs" (Dvorak et al., 1936, pp. 450–451).

Conclusion

In comparing the efficiency of the Dvorak and the QWERTY keyboards, one body of research supports 15% to 50% increases in speed for the Dvorak keyboard. Another body of research considerably reduces the size of this increase. A possible explanation for some of the discrepancy lies not with the keyboard but with the instructional technology. Dvorak's typists were responding to his methods of instruction as well as to his keyboard. Although many of the "high gain" studies are not clear regarding the instructional methods used, the QWERTY typists in comparison groups may have received instruction that had less "scientific management." In addition, many of the "low-gain" studies show no indication that they incorporated Dvorak's particular teaching methods. In fact, the low-gain studies are generally distinguished by the fact that they gave less time to instruction and less time to considerations that would facilitate performance.

The importance of treatment conditions in comparing the keyboards is illustrated by the Australian Post Office study of 1952 cited by Yamada (1980). In this study, "clear evidence" for the advantage of the Dvorak keyboard over the QWERTY keyboard did not emerge until incentives were added as a common condition in a follow-up investigation. In the Strong (1956) study, the effects of charting may have been used to put the Dvorak typists at a disadvantage. Both the Dvorak and QWERTY groups were introduced to instructional conditions that included charting. However, the group retrained on the Dvorak keyboard received instruction first and had not yet regained their previous rate of accuracy

when the control group of QWERTY typists were brought into the classroom for the experimental comparison. In comparison to the Dvorak typists, the QWERTY typists may have been more susceptible to sudden gains in performance when they were exposed to charting for the first time. Thus the magnitude of these gains may be partially attributed to a "Hawthorne effect" on the control group. In Parsons' (1974) re-analysis of the studies at Hawthorne, he attributed the effect to the introduction of charting and other scientific management principles and interpreted it in terms of operant conditioning.

Certainly, more information is necessary to determine how much the instruction or the keyboard contributed to the gains reported. Based on the information currently available, however, it appears that Dvorak's teaching techniques were an important contribution to the gains reported with his keyboard.

The above account of Dvorak's keyboard illustrates some of the problems facing the acceptance of an innovative technology. There may be a considerable variety of barriers to overcome before a technological innovation with proven advantages is adopted (cf. Rogers, 1983). This is shown not only in the failure of the Dvorak keyboard to replace the QWERTY keyboard but also in the historical resistance to using typewriters and typewriting techniques (Yamada, 1980). Even today, many young children do not use keyboards for writing in school despite the abundant documentation for the academic advantages of using the typewriter (Moxley, 1982).

In addition, Dvorak's work illustrates how behavior analysis is particularly well-suited to the study of organism-machine interactions. It is difficult to imagine a more appropriate application for the principles of behavior analysis than the study of student-keyboard interactions. Button pressing has been described as a ubiquitous feature of psychological investigations in the laboratory (Harzem, 1986, p. 46), and Skinner (1986), in an article that describes the small computer

as the "ideal hardware for programmed instruction" (p. 110), points out how "pushing is reinforced when something moves, quite apart from anything that happens afterward" (p. 108). When we further consider that keyboarding easily lends itself to an analysis in terms of *stimulus-selection-based* and *topography-based* verbal behavior for hunt-and-peck and touch typing, respectively (see Michael, 1985, p. 2), it is surprising that keyboarding has not received more attention from behavior analysts. There is a scientific need for an experimental analysis of human operant behavior as it relates to the keyboard. This would have significance for understanding the development of keyboarding skills as well as the verbal behavior produced by those skills. There is also a socially important need to apply the principles of behavior analysis to the acquisition of early literacy through the keyboard, an integral component of the "ideal hardware for programmed instruction."

REFERENCES

Adler, M. H. (1973). *The writing machine.* London: George Allen & Unwin.

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Cassingham, R. C. (1986). *The Dvorak keyboard.* Arcata, CA: Freelance Communications.

David, P. (1985). Clio and the economics of QWERTY. *The American Economic Review, 75,* 332–337.

Dvorak, A. (1943). There is a better typewriter keyboard. *National Business Education Quarterly, 12,* 51–58, 66.

Dvorak, A., Merrick, N., Dealey, W., & Ford, G. (1936). *Typewriting behavior: Psychology applied to teaching and learning typewriting.* New York: American Book Company.

Gantt, H. L. (1974). *Organizing for work.* Easton, PA: Hive Publishing Co. (Original work published 1919.)

Gentner, D. R., & Norman, D. A. (1984). The typist's touch. *Psychology Today, 18,* 66, 68, 70–72.

Gilchrest, E. (1916). The extent to which praise and blame affect a pupil's work. *School and Society, 4,* 872–874.

Harzem, P. (1986). The language trap and the study of pattern in human action. In T. Thompson & M. D. Zeiler (Eds.) *Analysis and integration*

of behavioral units (pp. 45–53). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hiraga, Y., Ono, Y., & Yamada, H. (1980). *An analysis of the standard English keyboard* (Report No. 80-11). Tokyo: University of Tokyo, Department of Information Science.

Hoffer, W. (1985). The Dvorak keyboard: Is it your type? *Nation's Business, 73,* 38–40.

Kinkead, R. (1975). Typing speed, keying rates, and optimal keyboard layouts. *Proceedings of the 19th Annual Meeting of the Human Factors Society, 99,* 159–161.

Lemmons, P. (1982). A short history of the keyboard. *BYTE, 7,* 386–387.

Litterick, I. (1981). QWERTYUIOP—dinosaur in a computer age. *New Scientist, 89,* 66–68.

McGreevy, P. (1984). Frequency and the standard celeration chart: Necessary components of precision teaching. *Journal of Precision Teaching, 5,* 28–36.

Michael, J. (1985). Two kinds of verbal behavior plus a possible third. *The Analysis of Verbal Behavior, 3,* 2–5.

Moxley, R. A. (1982). *Writing and reading in early childhood: A functional approach.* Englewood Cliffs, NJ: Educational Technology.

Navy Department, Division of Shore Establishments and Civilian Personnel. (1944). *I: A practical experiment in simplified keyboard retraining and II: A comparison of typist improvement from typing on the standard keyboard and retraining on the simplified keyboard.* Washington, D.C.: Author.

Neill, S. (1980). Dvorak vs. QWERTY: Will tradition win again? *Phi Delta Kappan, 61,* 671–673.

Norman, D., & Fisher, D. (1982). Why alphabetic keyboards are not easy to use: Keyboard layout doesn't much matter. *Human Factors, 24,* 509–519.

Parkinson, R. (1972). The Dvorak simplified keyboard: Forty years of frustration. *Computers and Automation, 21,* 18–25.

Parsons, H. M. (1974). What happened at Hawthorne? *Science, 183,* 922–932.

Pennypacker, H., Koenig, C., & Lindsley, O. (1972). *Handbook of the standard behavior chart* (preliminary edition). Kansas City, KS: Precision Media.

Rogers, E. M. (1983). *Diffusion of innovations* (3rd ed.). New York: Macmillan.

Schwartz, B., & Lacey, H. (1982). *Behaviorism, science, and human nature.* New York: W. W. Norton.

Sims, V. (1928). The relative influence of two types of motivation on improvement. *Journal of Educational Psychology, 19,* 480–484.

Skinner, B. F. (1986). Programmed instruction revisited. *Phi Delta Kappan, 68*(2), 103–110.

Strong, E. P. (1956). *A comparative experiment in simplified keyboard retraining and standard keyboard supplementary training.* Washington, D.C.: General Services Administration.

Taylor, F. W. (1947). *Scientific management.* New

York: Harper & Brothers. (Original work published 1911.)

White, O. (1986). Precision teaching—precision learning. *Exceptional Children, 52,* 522–534.

Yamada, H. (1980). A historical study of typewriters and typing methods: From the position of planning Japanese parallels. *Journal of Information Processing, 2,* 175–202.

Yamada, H. (1983). The Dvorak simplified keyboard: Practice belies theory. *Computer, 16,* 80–81.